Zero Emission Vehicle Study

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Table of Contents

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Section One Introduction

In 1990, the California Air Resources Board (CARB) adopted a zero emission vehicle (ZEV) program. The original ZEV mandate required that by 2003 10 percent of the cars sold in California emit zero tailpipe and evaporative emissions. Vehicles that meet these criteria are called "pure ZEVs." In 1998 CARB revised ZEV program to allow manufacturers to fulfill a portion of the ZEV mandate with a variety of vehicles, including those powered by internal combustion engines. The revised ZEV mandate is called the "partial ZEV" program.

To date the ZEV requirement has been instrumental in promoting battery and vehicle research and development. As a result, a variety of battery-powered electric vehicles are now available to fleets and the general public. The program has also been successful in spawning a large variety of extremely low-emission vehicle technologies, many of which may not have gained significant attention without the CARB ZEV requirements. Many of these technologies have at least some qualities inherent to ZEVs, such as extremely low emissions and extended durability, partial all-electric range or the use of an inherently durable non-combustion engine. In response to the growing alternatives to battery electric ZEVs, CARB developed the partial ZEV program. The program introduces significant flexibility into the ZEV mandate and broadens the scope of vehicles that can qualify for meeting some portion of the ZEV requirement.

Some of these advanced technology vehicles will have equivalent air quality benefits as battery electric vehicles, namely: zero tailpipe emissions, zero evaporative emissions and no emissions associated with refining of fossil fuels. However others will only provide partial benefits in comparison with battery electrics. The partial ZEV program is intended to encourage the development of these new advanced technology vehicles. The reason for establishing the additional flexibility in the ZEV program is two-fold:

1) new advanced technology vehicles are being manufactured that have ZEV-like characteristics including the ability to operate on all-electric power and near zero emissions; and

2) the jump to 10 percent ZEV sales in 2003 will be difficult for automobile manufacturers. The partial ZEV program encourages the introduction of advanced technology vehicles and smoothes the transition to the 2003 ZEV requirement.

When California first introduced the zero emission vehicle mandate in 1990 only battery electric cars could meet the zero tailpipe emission standard. While technology advances have been made, battery electric vehicles are still limited to certain niche markets due to a limited driving range and a lack of re-charging infrastructure. Other recent technology advances have made the sale of natural gas hybrids, gasoline hybrids, and near zero gasoline conventional vehicles a reality. In addition, auto manufacturers have announced development programs for fuel cell cars and anticipate introduction of these vehicles in the next five years.

The development of alternatives to battery electric vehicles will make the use of cars with zero tailpipe emissions possible for the general public. In many cases, the public will not even be aware that they are driving in an advanced technology vehicle. For example, the driver of a gasoline hybrid vehicle will re-fuel the car at a gas station, will have extended mileage, and enjoy performance that is identical to that of a current gasoline car. At the same time, these advanced technology vehicles will reduce pollution and fuel consumption significantly.

Section Two Background

California's Low Emission Vehicle Program

Emission standards for passenger cars were first established in California in 1965. U.S. federal standards followed in 1968. Over the past thirty years these emission standards and test procedures have become increasing more stringent resulting in significant reductions in motor vehicle emissions.

In September 1990, the California Air Resources Board (CARB) adopted Low-Emissions Vehicle regulations. These regulations required automobile manufacturers to introduce progressively cleaner light- and medium-duty vehicles with more durable emission controls. The regulations included three major elements:

- They established a tier of vehicle categories to distinguish between increasingly more stringent exhaust emission standards for light- and medium-duty vehicles. In order of increasing stringency, the categories are:

  transitional-low-emission vehicles (TLEVs),

  low-emission vehicles (LEVs),

  ultra-low-emssion vehicles (ULEVs), and

  zero-emission vehicles (ZEVs).

- They required each manufacturer to phase-in a progressively cleaner mix of low-emission vehicles beginning in 1994 through 2003. Auto manufacturers may produce any combination of TLEVs, LEVs, ULEVs, and ZEVs as long as the fleet average requirement is met.

- Beginning in 1998, two percent of the vehicles produced and delivered for sale in California by the seven largest automakers were required to be ZEVs. That percentage increased to five percent in 2001 and ten percent in 2003.

In 1996 CARB eliminated the ZEV requirement from 1998 through 2002 while retaining the ten percent requirement for 2003 and beyond. In addition CARB directed its staff to enter into a Memorandum of Agreement with the seven largest automakers to participate in a Technology Development Partnership to accelerate the commercialization of advanced-battery vehicles by placing 3,750 demonstration ZEVs in California in 1998 through 2000. The automakers also committed to continued funding of ZEV-related technology research and development.

In November 1998 CARB amended its LEV regulations. The new amendments, known as LEV II, represent further emission reductions from motor vehicles. These standards extend the original LEV program from 2004 through 2010 with new requirements. The LEV II amendments affect passenger cars, light-duty trucks, and medium-duty vehicles. The main elements are:

- Extending passenger car emissions standards to heavier sport utility vehicles and pickup trucks (with gross vehicle weight up to 8,500 pounds) which formally had been regulated under less stringent emission standards;

- Extending and tightening of the fleet average emssion standards during 2004-2010;

- Creating a new super-ultra low emission vehicle (SULEV) category for light-duty vehicles;

- Significantly lowering of oxides of nitrogen emission standards for the low and ultra-low emission vehicle categories, a reduction of 75% from the current LEV standards;

- Increasing emission control durability standards from 100,000 miles to 120,000 miles for passenger cars and light-duty trucks;

- Further reducing of evaporative emissions; and

- Creating partial zero-emission vehicle (ZEV) credits for vehicles that achieve near zero emissions. (See Section Three of the report)

A biennial review of the CARB's Zero Emission Vehicle (ZEV) program is scheduled for September 2000. The purpose of the biennial review is to update the Board on progress being made towards meeting the ZEV program requirements. Staff to the Board will hold two workshops to present information related to the review and receive public comment for CARB's consideration.

At the first workshop, scheduled for March 29, 2000, staff will present preliminary information regarding the biennial review process, manufacturer status, current vehicle technology, and compliance with the Memoranda of Agreement. Staff will seek comment on the content of the preliminary staff assessment, and will invite comment on the experience of current EV drivers, and advances in ZEV drivetrains and other components. The preliminary staff assessment will be made available prior to the workshop.

At the May 31, 2000 workshop, CARB staff will present the draft Staff Report and Technical Support Document for the September Board meeting, with updated information on the topics referenced above, plus a discussion of costs, emission benefits, and the EV market. Staff will also present findings from an assessment of battery technology and manufacturing cost, currently being conducted by an external review panel.

Maine's Low Emission Vehicle Program

Under Section 177 of the Clean Air Act Amendments of 1990, states were allowed to adopt and enforce new vehicle standards which differ from the federal standards as long as such standards are identical to the California standards and are adopted at least two years prior to commencement of a model year.

Currently four northeast states have adopted the California Low Emission Vehicle program: Massachusetts (starting with model year 1996 motor vehicles); New York (starting with model year 1997), Vermont (starting with model year 1999), and Maine.

Maine adopted the California Low Emission Vehicle (LEV) standards on February 17, 1993, starting with model year 1996. However, legislation was subsequently passed stipulating that the effective date of the regulation was dependent on whether states in the northeast and the Ozone Transport Region also adopted similar rules. In December 1997, the Department notified the automobile manufacturers that the "triggers" had been met and that Maine's LEV program will start with model year 2001. This program includes California's Zero Emission Vehicle requirement.

In 1997, 38. M.R.S.A. Section 585-D was amended to require that "the commissioner shall complete a study of zero-emission vehicles and submit a report to the joint standing committee of the Legislature having jurisdiction over natural resources matters no later than January 1, 2000. This study must include an examination of zero-emission vehicle technology, price, performance and consumer acceptability and implementation issues relating to use of those vehicles in the State. The study must recommend any rulemaking necessary for the board to establish a zero-emission vehicle program that is appropriate for the State and a schedule that provides the automobile manufacturers with a minimum 2-year lead time prior to implementation of such a program. Any rules establishing a zero-emission vehicle program are major substantive rules pursuant to Title 5, chapter 375, subchapter II-A."

Section Three The Partial ZEV Program[1]

Partial ZEV Credit Program Overview

As mentioned above, the new partial ZEV program allows for and encourages the introduction of hybrid electric vehicles, reformer-equipped fuel cell vehicles, natural gas vehicles, and conventional gasoline vehicles with advanced emission control systems. These vehicles will be described in detail in Section Four of this report on technical feasibility. The partial credit scheme allows manufacturers to get credit towards the 10 percent ZEV mandate using these advanced technology vehicles. The credit system allows for credit to be taken in three different categories:

1) extremely low tailpipe emissions;

2) partial electric range capability; and

3) low emissions associated with processing the fuel used in the vehicle.

It is important to note that the partial ZEV credit program has one pre-requisite: all partial ZEVs must meet a tailpipe standard that is equivalent to the CARB certification level of a "Super Ultra-Low Emission Vehicle" or SULEV. This requirement ensures that all partial ZEV vehicles emit the same or less pollution than the power plant emissions that would be generated in re-charging a battery electric vehicle. The essential elements of the program are summarized below:

- A vehicle must meet baseline emissions criteria (SULEV tailpipe emissions);

- Each vehicle can potentially receive one ZEV credit if, and only if, it meets the baseline criteria, uses a clean fuel and can provide 120 miles of pure electric range;

- Vehicles that meet the baseline criteria, but not all of the others, will be limited to receiving less than one ZEV credit, even if the complete fuel cycle emissions associated with that vehicle are less than those of battery electric vehicles (BEVs);

- Vehicles with no ZEV range will not be able to satisfy the full 10 percent ZEV sales volume requirement. They will be allowed to satisfy up to 60 percent of the ZEV requirement;

[1] "parts of this section are excerpted from theCARB "LEV II and CAP 2000 Amendments Final Regulaory Order," 10/99

- Pure ZEVs must account for at least 40 percent of the 10 percent sales requirement.

Table 1 below compares advanced technology vehicles that are eligible for partial ZEV credit with ZEVs.

Table 1:
Comparison of ZEVs with Advanced Technology Vehicles

Advanced Technologies with Extremely Low-Emission or Zero-Emission Capability	Qualities in Common with ZEVs
Gasoline SULEV	Emissions comparable to EV-related power plant emissions and extended durability
Compressed Natural Gas SULEV	Same as above plus very low fuel-cycle emissions
Hybrid electric vehicle (HEV) with significant all-electric range	Partial zero-emission range
Methanol reformer fuel-cell vehicle[1]	Extremely low emissions
Direct methanol fuel-cell vehicle[1]	Extremely low emissions
Stored hydrogen fuel-cell vehicle[1]	ZEV
Battery-powered electric vehicle	ZEV

[1]Due to their inherent efficiency of operation, fuel cell vehicles can also result in reduced emissions of carbon dioxide, a greenhouse gas.

Determining Partial ZEV Credits

In the partial ZEV program a greater amount of credit is given to those vehicles that are closest to a true ZEV and a lesser amount is given for those vehicles that are closer to a conventional vehicle powered by an internal combustion engine. In the program, vehicles that have all of the characteristics of a ZEV (zero tailpipe and evaporative emissions; zero emissions associated with fuel refining; and all-electric driving range) are given one ZEV credit. Those vehicles that fulfill the minimum partial ZEV requirements and that have ZEV-like characteristics are given a fraction of one ZEV credit. The three ZEV-like characteristics that manufacturers can claim partial ZEV credits for (emissions, all-electric range potential; and emissions associated with fuel refining) are described below along with an explanation of how much credit can be taken for different ZEV-like characteristics. Manufacturers can claim up to 60 percent of the total ZEV mandate with partial ZEVs. The remaining 40 percent of the ZEV mandate must be fulfilled with true ZEVs.[2]

1) Emissions Standards

In order for a vehicle to receive any ZEV allowance, a vehicle would need to satisfy the requirements for receiving the "baseline ZEV allowance." To receive this allowance, the first requirement would be for the vehicle to at least meet the SULEV standard[3] at 150,000 miles and also satisfy applicable second-generation on-board diagnostics requirements (OBD II) and zero-fuel evaporative emission requirements. On-board diagnostics allow for the monitoring of engine and emission control components. Vehicles meeting the above requirements would receive credit equal to 1/5th of a full ZEV credit. In other words, a manufacturer must sell five SULEVs to receive credit for one ZEV. Considering one compliance scenario for the ZEV mandate, if a manufacturer chose to fulfill the entire 6 percent of partial ZEVs with SULEV cars, 30 percent of annual car sales would have to be SULEVs. The emissions associated with this and other possible ZEV compliance scenarios are detailed at the end of this section.

2) All-Electric Range Capability

An additional allowance is provided based on the potential for realizing zero-emission vehicle miles traveled (VMT) (e.g. capable of some all-electric operation traceable to energy from off-vehicle charging), up to a maximum of 6/10th of a ZEV credit. Many clean technologies, including some fuel-cell vehicles and hybrid electric vehicles, have the potential for zero emissions associated with some portion of the VMT. Under the revised ZEV program, such vehicles would receive a zero-emission VMT allowance, proportional to the estimated zero-emission VMT potential as a percent of total VMT which is the zero-emission VMT factor. To receive this credit, a manufacturer would need to provide an estimate of the likely zero-emission VMT potential of their particular vehicle design based on actual in-use data, an engineering evaluation of the vehicle's operational strategy and any other relevant information to validate the estimate.

$$\text{zero-emission VMT allowance} = 0.6 \times \text{zero-emission VMT factor}$$

Some manufacturers have developed hybrid electric vehicle designs that deliver improved fuel economy but do not have any significant all-electric range (the Toyota Prius and Honda Insight for example). Such vehicles do not qualify for a zero-emission

[2] The current program allows for 60 percent of the ZEV mandate to be fulfilled with partial ZEVs. CARB has scheduled a review of the ZEV mandate. At that time the program could be changed.
[3] Emissions from vehicles in this category are close to emissions associated with recharging electric vehicles in California. In the Northeast, power plant emissions associated with re-charging electric vehicles would be higher than in California due to the predominance of coal and oil burning power plants. Thus in the Northeast, SULEV vehicles will have lower emissions than true ZEVs assuming there is no deterioration in emissions over the life of the car.

VMT allowance because without wall re-charging capability that provides significant all-electric range; such vehicles would not exhibit the lowest emission characteristics. However, even though these vehicles would not receive any zero-emission VMT allowance under this category, they could receive some allowance under a provision explained in the next section.

Some vehicles have potential for zero-emissions for one regulated pollutant (e.g., NOx) while having low-levels of emissions of other regulated compounds (e.g., non-methane organic hydrocarbons or NMOG). One such vehicle could be an on-board methanol reformer fuel-cell vehicle. This vehicle has virtually no NOx emissions since the operational temperature of the reformer is typically lower than the temperature required for NOx formation. Consequently, in order to credit such vehicles for zero-emission capability of a specific pollutant, CARB allows for this vehicle to receive a zero-emission VMT factor of 0.5.

Vehicles that do not have significant zero-emission VMT potential but are equipped with advanced batteries, an electric power-train, and other advanced ZEV technologies can qualify for a zero-emission VMT allowance of 0.1. This additional allowance is provided in recognition of the vehicle's contribution to helping develop advanced batteries and powertrains that assist in commercializing ZEV technologies. One such vehicle would be the Toyota Prius, assuming it is designed to meet the SULEV standard. The Prius is equipped with a limited number of advanced nickel metal hydride (NiMH) batteries and an advanced electric drive-train.

3) Emissions Associated with Fuel Refining and Distribution

Another characteristic that qualifies a vehicle to receive an additional ZEV allowance is the use of fuels with very low full fuel-cycle emissions to propel the vehicle. Under this proposal, a vehicle that uses fuel(s) with very low fuel-cycle emissions can receive a ZEV allowance up to a maximum of 0.2. The fuel-cycle emissions associated with a particular fuel are the total emissions associated with the production, marketing and distribution estimated as grams per unit of fuel. These emissions are then converted into grams/mile by applying the fuel-economy estimate of the vehicle. In order to receive this allowance, a manufacturer must demonstrate, using peer-reviewed studies or other relevant information that marginal NMOG emissions associated with the fuel used by the vehicle are lower than or equal to 0.010 grams per mile. It should be noted that for the purpose of providing this allowance, fuel-cycle NOx emissions are not considered in the determination since marginal NOx emissions for virtually all fuels are uniformly very low. Fuel-cycle emissions must be calculated based on near-term production methods and infrastructure assumptions. At this time, it appears that only gaseous fuels could very likely qualify for this allowance. Some liquid fuels, for example methanol, may also qualify with vehicle efficiency improvements and with the use of improved refueling evaporative controls.

If more than one fuel is used to propel a vehicle, then this ZEV allowance is awarded based on the percent of total vehicle miles traveled using fuel(s) with low fuel-cycle emissions. To illustrate, assume a hybrid electric vehicle with significant all-electric range uses off-vehicle charging electrical energy to propel the vehicle for 70 percent of the total VMT and another fossil fuel (e.g. gasoline) for the remaining 30 percent of the total VMT. In this case, only the off-vehicle electrical energy use meets the low fuel-cycle emission requirement. Consequently, the ZEV allowance awarded to this vehicle would be 70 percent of 0.2, which is equal to 0.14.

The partial ZEV allowance awarded to a specific vehicle, then, is the sum of the allowances earned by the vehicle including the baseline, zero-emission VMT and low fuel-cycle emissions. Table 2 summarizes partial ZEV allowances:

Table 2:
Partial ZEV Allowance Proposal

Characteristic	**Pre-requisite or optional requirement?**	**ZEV allowance**
Baseline allowance - Meets SULEV at 150K & 150K emission warranty	Pre-requisite for vehicles to receive any allowance	0.2
Zero-emission VMT allowance (1)(2)	Optional – qualifies vehicle for additional allowance	(0.6 x zero-emission VMT factor)
Low fuel-cycle emission allowance	Optional – qualifies vehicle for additional allowance	up to 0.2
Partial ZEV allowance		**Sum of the above**

The CARB program requires that 40 percent of the ZEV requirement be met by true ZEVs and vehicles that receive a ZEV allowance of one. This would serve to ensure sufficient production volumes of advanced battery electric vehicles, stored hydrogen fuel-cell vehicles or other non-emission vehicles that do not deteriorate. Maintaining this production requirement can help ensure continued technical development and pilot production process optimization and afford some economies of scale to help make these true zero-emitting vehicles affordable and more competitive in the 2005 to 2010 time frame.

Small and intermediate volume manufacturers have indicated that it would be cost-prohibitive for them to individually produce very low volume advanced technology true ZEVs in the foreseeable future, given the relatively small number of vehicles that would be required to meet 40 percent of the ZEV requirement. Consequently, in order to address this concern, CARB allows intermediate volume manufacturers to satisfy the 10 percent ZEV requirement using only partial ZEV allowances, if they choose to do so.

Under this program, qualifying technologies receive an allowance ranging from 0.2 ZEV credit to multiple ZEV credits depending on their emission characteristics, use of advanced technologies to make vehicles that are more acceptable to consumers and other factors. The program provides manufacturers the flexibility to produce vehicles qualifying for ZEV credit that they envision would be most successful in the market place and would best meet consumer expectations. Overall, the program allows considerable flexibility to manufacturers, incenticize new near-term zero-emission technologies, and maintain the true ZEV development efforts -- eventually yielding more near zero emission reduction options than might otherwise be achieved.
Table 3 provides examples of advanced technology vehicles and the partial ZEV credits or allowances that would be earned from their ZEV-like characteristics.

Table 3:
Examples of Partial ZEV Allowance Calculation

Technology/Manufacturer	Baseline Allowance	Zero-emission VMT allowance	Low fuel-cycle allowance	**Partial ZEV allowance [3]**
Gasoline SULEV	0.2	0.0	0	**0.2**
Hybrid gasoline SULEV with no all-electric range (AER), equipped with advanced Batteries, electric powertrain	0.2	0.1	0	**0.3**
CNG SULEV	0.2	0.0	0.2	**0.4**
Gasoline Hybrid SULEV w/ 20-mile AER, off-veh. recharging	0.2	0.3	0.1	**0.6**
On-board methanol reform. Fuel Cell (FC) vehicle	0.2	0.3[1]	0.2[2]	**0.7**
Hybrid SULEV with NIMH bat. (60 whr/kg) and 100-mile range.	0.2	0.6	0.2	**1.0**
On-board hydrogen FC vehicle w/ off-board partial oxidation reforming of hydrogen using fuel with low fuel-cycle emiss.	0.2	0.6	0.2	**1.0**

1) Assumes on-board methanol reformer produces virtually no NOx emissions
2) Assumes methanol has very low fuel-cycle emissions
3) Partial ZEV allowance= Baseline allowance + Zero-emission VMT allowance + Low fuel-cycle allowance

California Equivalent Low Emission Vehicle (EZEV) Standard

The California Air Resources Board (CARB) amended the LEV program to add a new equivalent zero-emission vehicle (ZEV) emission standard. This new standard is based on California in-basin power plant emissions of NOx and reactive organic gases (ROG) associated with charging battery-powered electric vehicles. Vehicles certifying to the EZEV standard would need to demonstrate exhaust, evaporative and refueling emissions that, in combination, fall below the EZEV certification standards. Vehicles certified to the EZEV standard would be credited toward a manufacturer's ZEV requirement on a one-to-one basis. The certification standards for non-methane organic gas (NMOG), NOx, particulate matter (PM), and carbon monoxide (CO) are:

Table 4:
EZEV Certification Standards Compared with ULEV Certification Standards

Pollutant	ULEV standard (Grams per mile)	EZEV Emissions Level (Grams per mile)
NMOG	0.040	0.004
NOx	0.2	0.02
PM	--	0.004
CO	1.7	0.17

Section Four States Adoption of the California ZEV Program

Section 209(a) of the Clean Air Act prohibits states from adopting or attempting to enforce "any standard relating to the control of emissions from new motor vehicles." There are two exceptions: (1) California may adopt more stringent standards after receiving a federal waiver (section 209(b)), and (2) other states may adopt the California vehicle emissions standards as long as the standards are identical to those in California (section 177).

As a means of attaining the federal health standards for ozone, Massachusetts and New York adopted the California LEV program with the ZEV mandate in the early 1990's. In the spring of 1996, California repealed its ZEV mandate from 1998 to 2002, leaving in tact the ten percent sales requirement in 2003. Simultaneously, CARB and the car makers signed private contracts, referred to as Memoranda of Agreement (MOAs), which require the manufacturers to produce for sale 3,750 advanced battery electric vehicles from 1998 to 2000.

Several months later, Massachusetts amended its LEV regulations to scale back the ZEV mandate to 3,750 ZEV from 1998 to 2000 in order to maintain a program that is identical to California, as required under section 177. In New York, the mandate was left as the original California program.

In 1997, the Second Circuit Court of Appeals ruled that the New York program could not be adopted. In Massachusetts, the court asked for EPA's opinion on whether or not the California ZEV mandate is a "standard" rather than an enforcement action. The US EPA opinion was recently summarized in a letter to the First Circuit Court of Appeals. EPA's opinion is that the Massachusetts' zero emission vehicle (ZEV) mandate is a "standard" and not preempted under the Clean Air Act. Specifically, the Agency found that the ZEV mandate is an integral part of the California Low Emission Vehicle (LEV) program subject to the identicality restrictions of the Act. In addition, the Agency found that the provisions of the MOAs[4] should be considered standards since they grew directly out of the ZEV regulatory requirements and were intended to stand in their place and serve the same function. If adopted by the First Circuit in its ruling on the Massachusetts ZEV case, EPA's decision means the following:

- The largest automobile manufacturers[5] must produce for sale up to 3,750 ZEVs in Massachusetts by 2000, or pay a penalty for each vehicle not delivered for sale.
- Any state adopting the California LEV program within the jurisdiction of the First Circuit must also adopt the ZEV mandate.

[4] The Memorandums of Agreement (MOAs) are private contracts between California and each of the seven largest automobile manufacturers. A possible purpose of placing the ZEV requirements in private contract rather than regulation was to prevent the Northeast states (e.g., New York and Massachusetts) from requiring the car makers to produce ZEVs in the Northeast.

[5] GM, Ford, Daimler-Chrysler, Toyota, Honda, Nissan.

- EPA's decision on the legal status of the ZEV mandate is likely to persuade other federal appellate courts seeking to rule on this issue.

- California is unlikely to enter into another MOA with the automakers since such an action is not likely to prevent other states from adopting its provisions as if they were in regulation.

A final decision from the court is pending on the Massachusetts ZEV mandate.

It is likely that as a result of the anticipated First Circuit Court of Appeals decision and the U.S. EPA decision, states that adopt the California LEV II program will also adopt the ZEV mandate. As a result, all Northeast states that are participating in the California Low Emission Vehicle (LEV II) program (some states have adopted the LEV program without the ZEV mandate) will receive between 15 and 25 percent of new vehicles sales as advanced technology vehicles starting in 2003. For example, under certain reasonable assumptions, Massachusetts may expect to receive about 2,000 all-electric-range EVs, about 20,000 hybrid electric vehicles, and 30,000 gasoline or natural gas-powered SULEVs with zero evaporative emissions in 2003 under LEV II. This large number of Advanced Technology Vehicles (ATV) may be expected to provide significant air quality benefits to participating LEV II states, and place the Northeast at the forefront of automotive technology advancement.

Northeast States Adopting the ZEV Mandate

Assuming that the First Circuit adopts EPA's rationale, and other federal courts find EPA's decision persuasive, this decision effectively eliminates the threat of another MOA that might have placed all or part of the LEV II ZEV mandate out of reach of the Northeast states. The LEV II ZEV mandate is likely to become effective in Massachusetts, New York, Vermont and Maine. Under its provisions, it is likely that in the early years (2004-2007), car makers will produce about 1 percent of their fleet as all-electric-range EVs, and about 15 to 20 percent of their fleet as a mixture of gasoline-powered SULEVs and hybrid electric vehicles. These vehicles must meet the requirements of a partial ZEV: zero evaporative emissions, 150,000 warranty, and emissions comparable to an EV charged off the California power grid.[6]

The partial ZEV credit scheme results in significant numbers of vehicles for participating northeast states. For instance, Massachusetts might expect about 20,000 hybrid-EVs, and New York might expect about 40,000, under certain conditions (see Table 6 below.) For comparison, the seven largest automakers have only leased several hundred EVs in California since 1997. In total, the partial ZEV credit requirement may require a large portion of new vehicles sales (20-25 percent) to meet SULEV standards with gasoline, natural gas, hybrid electric, or fully electric vehicles. The air

[6] As noted earlier, California utilities are far cleaner than the Northeast power grid, especially for NOx.

quality benefits associated with these very low emission standards, and the lack of deterioration and fuel efficiency of electric vehicles, are not insignificant.

Table 6:
Possible Compliance Scenario for ZEV Mandate (2003+)

State	1995 New Car Registrations	Pure ZEVs (4%)	Partial ZEVs Hybrids (10%)	Partial ZEVs SULEVs (15%)
Massachusetts	203,806	8,152	20,380	30,450
Maine	29,438	1,177	2,943	4,410
Vermont	19,121	764	1,912	2,865
New York	491,434	19,657	49,143	73,710

Table 6 provides a possible compliance scenario with the ZEV mandate. The scenario assumes that the ZEV mandate will require four percent of vehicles to be pure ZEVs. It is also important to note that only light duty vehicles, and not sport utility vehicles (SUVs) and trucks heavier than 3,750 lbs. are included in the estimate since the ZEV mandate only applies to lightest vehicles. Thus, while the number of cars and trucks registered in Maine was approximately 50,000 in 1995, only the light duty portion, approximately 29,000 was used for this calculation.

For the purpose of this analysis, it is assumed that carmakers would meet 60 percent of the ZEV mandate with partial ZEVs. Honda’s Z-LEV technology for gasoline vehicles and the current auto maker interest in hybrids led to the conclusion that gasoline-SULEV and hybrids will dominate the partial ZEV credit market from 2004 to 2011. Up to five SULEVs must be produced for sale to generate one ZEV credit (depending on whether they have other ZEV-like characteristics). As was shown in Table 4 a “no all-electric-range” hybrid electric vehicle will generate .3 ZEV credits, thus it takes 3.3 hybrids of this type to generate one ZEV credit. Assuming an even split between SULEV and hybrid partial ZEV vehicle types, carmakers must produce 15 percent SULEVs and 10 percent hybrids starting in 2004 for a total of 25 percent of new vehicle sales.

Section Five Technical Feasibility

In 1995, the only electric vehicles for sale in the U.S. were "conversions" of regular gas cars, there were no hybrid-electric vehicles available, and fuel cells were barely being discussed. Today, all the major automakers have made electric vehicles available, with over 3,300 EVs produced by the major auto manufacturers on the road in the U.S.; Toyota has sold over 30,000 of its hybrid-electric sedan, the Prius, in Japan and is bringing it to the U.S. this year; Honda is already selling a hybrid vehicle, the Insight, in the U.S.; and all of the major car companies have made large investments in fuel cell technology, with commitments to introduce fuel cell cars by 2010 or earlier.

Much of the focus of this clean vehicle technology development has been in California, New York and Massachusetts, the ZEV mandate states. As automakers continue to develop and promote clean cars, it seems likely that they will focus their efforts on those areas of the country where they receive incentives or must fulfill regulatory obligations. This "Technical Feasibility" section reviews the clean, advanced vehicle technologies currently available and those that will likely become available within the ZEV mandate time frame.

Battery Electric Vehicles

Electric vehicles are the only cars available that have no tailpipe emissions. EVs are already available in the U.S. -- primarily, but not exclusively, in those states that have a ZEV mandate. Most of the major automakers currently offer EVs for sale or lease, as do some smaller manufacturers including Massachusetts-based Solectria.

Definition

A battery electric vehicle is one that uses an electric motor powered by a battery pack, instead of using an internal combustion engine. The California Air Resources Board has designated the battery EV as the only car currently to meet CARB's zero emission vehicle classification, which requires that the car have no tailpipe emissions, no evaporative emissions, no emissions from gasoline refining or sales, and no on-board emission control systems that can deteriorate over time.

Like the hybrid, an electric car is equipped with regenerative braking, which allows it to recapture braking energy. Since, unlike a hybrid, an EV does not use a gas engine, it must be equipped with a fairly large battery pack, depending on the type of battery used and the weight of the vehicle. There have been significant advancements in battery technology over the past 5 years, in part due resulting from a federal/industry partnership known as the U.S. Advanced Battery Consortium. Initially, most EVs were equipped with lead acid batteries; today, they are more likely to use nickel metal hydride batteries, as well as other advanced battery technologies (See below for more discussion of battery technology).

Performance

Any potential EV driver should be aware that current EV technology does not provide performance comparable to gas cars. However, EVs can easily meet the range needs of many daily commuters and fleets. For example, lead acid powered EVs typically can travel between 50 and 70 miles on a single charge. According to the U.S. Department of Transportation, the average daily commute, round-trip, is 22 miles and the average shopping trip is 10 miles, round-trip – both well within the typical EV range. EVs are also viable in fleet applications where the vehicles drive relatively short routes. And, EVs equipped with the more advanced nickel metal hydride batteries can have up to twice as much range, although the range will differ significantly for different types of vehicles.

Developments in Battery Technology

Battery technology is the biggest factor in making EVs commercially viable – both in terms of providing range comparable to a gas car and in making EVs affordable. Because of its importance, battery development has received large investment from industry and the government over the past 10 years. The results have been significant advancements in the technology. Five years ago, most EVs were powered by lead acid batteries, which, depending on the weight and efficiency of the car, provided from 50 to 70 miles of range on single charge. Most EVs today are powered by "advanced" batteries, such as nickel metal hydride or lithium ion batteries. This translates into longer range and the ability to power larger vehicles with batteries. For example, the electric versions of the Ford Ranger, Chevy S-10 and Toyota RAV-4 all use nickel metal hydride battery packs. Lithium ion is another leap in battery technology. Nissan equipped its electric sedan, the Altra, with lithium ion batteries, giving it a real world driving range of up to 100 miles.

The following is a quick look at the range offered by each of the major EVs being offered today:

VEHICLE	BATTERY	DRIVING RANGE
GM EV1	Lead Acid	50 – 70 miles
GM EV1	Nickel Metal Hydride	80 – 120 miles
Chevrolet S-10	Nickel Metal Hydride	50 – 70 miles
Honda EV Plus	Nickel Metal Hydride	70 – 90 miles
Ford Ranger	Nickel Metal Hydride	50 – 70 miles
Toyota RAV4	Nickel Metal Hydride	60 – 80 miles
DaimlerChrysler EPIC	Nickel Metal Hydride	70 – 80 miles
Solectria Force	Lead Acid	50 miles
Solectria Force	Nickel Metal Hydride	80 – 100 miles
Nissan Altra	Lithium Ion	60 – 80 miles

Information courtesy the California Air Resources Board and EV America

Cold Weather Driving

One of the primary EV performance issues is cold weather driving. Low temperatures can have a negative effect on the EV battery pack and, therefore, the vehicle range. In addition, cold weather conditions create operational inefficiencies for all types of vehicles, resulting in increased on-road energy consumption. The Vermont Electric Vehicle Demonstration Project, conducted by EVermont, explored the issue of cold weather driving and concluded that EVs equipped with proper thermal management systems can operate effectively even in extreme low temperatures. The project tested three Solectria Forces, equipped with nickel metal hydride batteries, driving the vehicles during warm and cold weather in Vermont and Canada. Initially, the demonstrations showed that the range of the nickel-metal hydride EVs is reduced to about 65% of that during moderate temperatures. By comparison, a regular gas car's range is reduced to approximately 80%. However, with appropriate cabin and battery thermal management, the study concluded, a NiMH EV can increase the range by about 23%.

Infrastructure[7]

EVs must be plugged in to recharge the batteries. Right now, there are still two different charging options being used by automakers -- this is one area that is not "standardized" across the electric vehicle market. One charging option is called "conductive" charging. Conductive charging systems use a plug and cord system which can vary by the type of connector used and the level of voltage and current. The other option is "inductive" charging, which uses a special "paddle" that transfers energy to the vehicle by means of magnetic induction.

[7] Charging information courtesy the Electric Vehicle Association of the Americas

Both types of systems may require special electronics off the vehicle, although it is possible for some conductive charging to be done on a regular household outlet. For example, Solectria's EVs simply require a standard 220 volt outlet, such as would be used for large household appliances like a clothes dryer. The length of time for a recharge depends on the battery. But, in general, an EV would require a minimum of two to three hours of charging at the 220 level, and possibly as much as eight hours, making this option best for overnight charging at home or daytime charging at the workplace. Fast charging technology has been developed that can dramatically reduce the charge time. This method uses a high-powered system that can provide a full charge in as little as ten minutes

With regard to the cost of charging an EV, the Electric Vehicle Association of the Americas has said that, while costs will vary depending on the time of day you charge the vehicle, your utility rates, and the type of EV you drive, it is almost certain that an EV driver will pay substantially less than the cost of refueling a gas car. The average monthly fuel cost for a typical EV driver is expected to be less than $15, compared to $50 for gasoline. As with gas cars, the heavier the car and the more aggressively it is driven, the lower the fuel economy will be.

Emissions

EVs are the only vehicles currently available that offer zero emission operation, emitting no pollutants and no carbon dioxide. Even when taking into account the emissions associated with producing the electricity to charge the vehicle, EVs come out ahead. The primary reason for this is that electric motors are three to four times as efficient as traditional internal combustion engines. In addition, power plants are required to meet more stringent emission standards than motor vehicles and, unlike motor vehicles, have maintenance performed by professionals, as well as routine government oversight and emissions testing. Pollution is easier to control from a few power plants than from millions of cars. Finally, EVs will become even cleaner as the electric utility industry moves more toward clean, renewable energy sources.

Availability

As already noted, there are quite few EVs available in the U.S. Most of them are offered in California and the Northeast.

Chevrolet S-10**:** GM has developed an electric version of its Chevrolet S-10 Pickup for the fleet market. GM put a 114 horsepower, AC Induction Motor and Delco lead acid battery pack into a standard S-10 pickup, using the same frame, chassis and suspension found in the gas-powered S-10. The electric version is available in a regular cab
configuration with a short box and two-wheel drive. It has a payload of 950 lbs and was designed to meet the demands of commercial fleet operations**.**

With the lead acid battery pack, the S-10 has an effective range of 40 – 60 miles, depending on weather and road conditions and how the car is driven. The battery can be fully recharged in just 10 minutes using a Magne Charge Inductive Fast Charger. With regular inductive charging, it takes 2 – 3 hours. A fully charged S-10 Pickup Electric accelerates 0-50 mph in 10.3 seconds, 13.5 seconds at 50% charge. The S Pickup Electric features standard front-wheel drive, anti-lock brakes, a driver's side air bag, daytime running lamps and air conditioning.

The electric S-10 is available to fleets for $32,995. Since the S-10 became available in late 1996, approximately 490 have been sold.

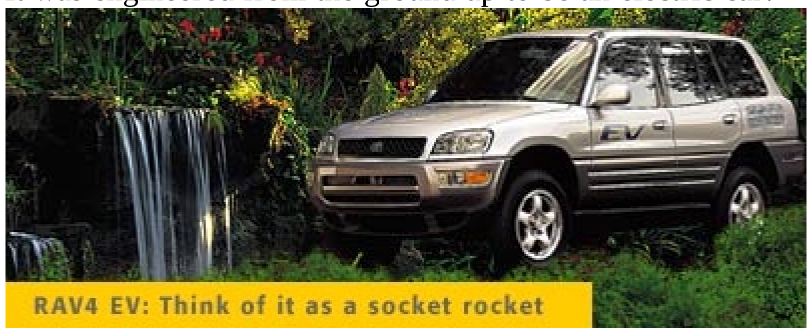
For more information on the S-10, go to www.gm.com/vehicles/innovations/chevys10.html

Ford Ranger: The other battery-powered pickup available today is the Ford Ranger EV, an electric version of Ford's compact truck. The Ranger EV uses a 90 horsepower AC induction motor. It comes equipped with either lead acid batteries or advanced nickel metal hydride batteries. The lead acid batteries give it a range of about 50 miles, with an electronically controlled top speed of 78 mph. In 1999, Ford began offering the NiMH battery powered version, which has an 80 mile range. It takes about 6 – 8 hours to fully recharge the batteries using an on-board conductive charger.

The lead acid Ranger is available for $34,999, or a $349 monthly lease. The nickel metal hydride version is available for $48,995 or a $614 monthly lease.

For more information go to wwwu.ford.com/electricvehicle/ranger.

***Toyota RAV4*:** Currently, the only electric SUV available is the Toyota RAV4-EV. After testing the electric RAV4's in Japan and the U.S., Toyota began marketing them in the U.S., primarily to fleets and primarily in New York and California, in 1997. Although it is based on an existing gas-powered vehicle, the 5-passenger RAV4-EV is not actually a conversion. It was engineered from the ground up to be an electric car.



The RAV4-EV uses a 50 kW, 67 horsepower permanent magnet motor and a nickel metal hydride battery pack. This gives the car a combined city/highway driving range of approximately 125 miles, although the range varies in different weather conditions. The top speed is governed at 78 mph and its payload is around 827 lbs. It uses an inductive charging system, which, until recently, was on board the vehicle. Toyota has also unveiled a new model of the RAV4 with an off-board charger, helping to lower the vehicle weight. It takes 6 – 8 hours for full recharge of the batteries.

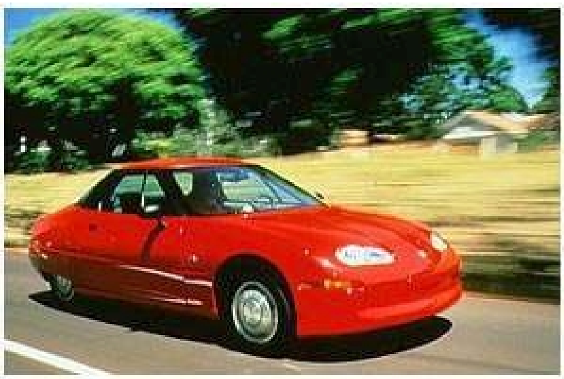
The RAV4-EV is currently available only in California, Massachusetts and New York. Toyota is targeting fleet users who are willing to buy or lease a minimum of 10 vehicles. The price of the new RAV4 $44,222. Since the car's introduction in 1997, 636 RAV4-EVs have been sold or leased in the U.S..

Daimler Chrysler EPIC: As the biggest seller in the minivan market, Daimler Chrysler chose to develop an electric minivan based on the 1999 Dodge Caravan. Dubbed the EPIC, it's the only electric minivan being produced today. The EPIC is powered by a 100 horsepower, AC induction motor and SAFT nickel metal hydride batteries. The NiMH battery pack gives the van a range of about 96 miles in combined city/highway driving. The range is likely somewhat less in cold weather. This is a heavy vehicle – 5800 lbs. GVW – with a 925 payload, so it takes 17 seconds to accelerate from 0 – 60 mph. As with many EVs, the top speed is governed at 80 mph. It uses an off-board conductive charger which recharges the EPIC in five hours. The EPIC is also capable of taking a "fast charge" which lowers the charge time to only 30 minutes.

The EPIC is available to fleets in California and New York for $450/month for a three-year period. The off-board charger is included in this price.

The EPICs were manufactured on the same production line that builds the Dodge Caravan. In February 1999, 120 were placed on dealers' lots in California for lease by interested fleets; over 75 have been leased (25 in New York). In February of this year, DaimlerChrysler delivered 45 electric EPICs to the U.S. Postal Service in San Diego.

General Motors EV1: The GM EV1 was the first production electric vehicle by a major automaker to be made available in the U.S. A two-seater with a distinctive tear-drop shape, this vehicle was designed to be a showcase for GM's electric vehicle technology. Although clearly not intended as a family or fleet car, the EV1 delivers high performance and comfort. GM just introduced a new version of the EV1 – Generation II (Gen II). Gen II is powered by a 137 horsepower, 3-phase AC induction motor and according to GM, the new drive system is half the size and cost of the first generation of EV1. Gen II will have two battery options: a nickel-metal hydride (NiMH) battery pack or a new, advanced lead-acid battery pack. GM reports that the NiMH pack will give the EV1 a real-world range of 75 – 130 miles, depending on temperature, terrain and how the car is driven. The advanced lead acid batteries give the car an estimated 55 – 95 mile range, a 20 – 30% improvement over the 1997 EV1. The EV1 uses inductive charging, which requires a special off-board 220-volt charger (the price is included in the total lease price). The new lead acid batteries will recharge from 20% to 80% in 2 or 2.5 hours; total recharge (from 0 – 100%) takes about 5.5 to 6 hours. It takes six to eight hours for a charge from zero to complete for the NiMH batteries. It is not clear yet whether the batteries can be "fast-charged", which could reduce the full charge time to one hour.



The EV1 was designed and built "from the ground up" to be an EV, so it was designed to be far more efficient than standard gas cars. The space frame is made of aluminum, the body panels from composite plastic. According to GM, the EV1 is the most aerodynamic and energy-efficient vehicle in the world today. This translates into high performance for an EV -- the EV1 accelerates from 0 – 60 mph in 8.5 seconds – faster than many gas cars.

The EV1 is available for lease only in California and Arizona. This is because of the advantageous climate conditions; tax and other incentives that draw down the lease price; and, of course, the need to fulfill California's ZEV mandate. However, the EV1 is also available to "select fleets". For example, Georgia Power has 26 EV1s and will be acquiring more as part of a program to make the cars available to employees.

The lease price for the new advanced lead acid EV1 is $33,995, which translates into a monthly lease payment $574. This price drops down to $424 in some parts of California thanks to federal and local tax incentives. The NiMH version costs $43,995 to lease. Since its introduction in December 1996, the EV1 has reached sales of 591 units.

For more information go to www.gmev.com.

Solectria Force: Since the first Force was sold in 1991, Solectria has sold roughly 200 of these electric sedans. It is a production "conversion" vehicle, available with lead acid, nickel metal hydride or nickel cadmium batteries. The lead acid version has a range of approximately 50 miles; the NiMH version range is 100 miles; and the nickel cadmium version goes approximately 85 miles on a single charge. The Force has been used extensively in cold weather testing and is used by fleets and individual drivers throughout New England. It is available across the United States. Pricing information is available only from Solectria.

The Maine Electric Vehicle Project currently "shares" a 1995 Solectria Force.

For more information, go to www.solectria.com

Hybrid-Electric Vehicles

Currently, hybrid-electric vehicles are the advanced technology vehicles receiving the biggest marketing "push" from automakers. The hybrids being shown today combine an electric motor with a gas or diesel engine to significantly increase fuel efficiency and lower emissions. Honda and Toyota are already selling hybrids: Toyota introduced the *Prius* in Japan in December 1997, and Honda launched the Insight in the U.S. in December 1999. Sales of the Prius in Japan have topped 30,000 units; in fact, monthly production had to be ramped up to meet the unexpectedly high demand. Now, other major automakers, including General Motors, Ford and DaimlerChrysler, are issuing public commitments to introduce hybrid vehicles to the U.S. market.

Definition

What exactly is a hybrid-electric vehicle? A hybrid-electric vehicle, or hybrid, has two sources of motive energy on board the vehicle. The combination of a diesel or gas engine with an electric motor is what most passenger hybrid vehicles use today – it's found in the Prius and the Insight, as well as two prototype hybrids unveiled recently at the Detroit Auto Show. A hybrid could also combine other elements such as a gas turbine, ultracapacitor or flywheel; however, this report will speak only to the electric motor/gas engine combination that will drive hybrids coming to market in the next few years.

The benefits of a hybrid system are better mileage, lower emissions, ease of use, and performance comparable to regular gas cars. How these different benefits stack up depends on how the hybrid system is configured. There are numerous ways to design a hybrid system, and, thus far, automakers are each developing slightly different systems that trade-off the costs and benefits differently. There are three general categories for a hybrid configuration:

- A hybrid can use the electric motor only as an assist to the gas engine;
- It can use both the electric motor and the engine to power the wheels; and
- It can use only the electric motor to power the wheels, with the gas engine serving to supply energy to the motor or battery.

With hybrids that use the electric motor to assist the engine, the motor typically kicks on only when the car starts from a stop, during rapid acceleration, or on steep climbs. The key advantage of the hybrid system in this configuration is that it allows the car to utilize regenerative braking. With regenerative braking (regen), energy normally lost during braking can be recovered and stored in the battery. This is not an insignificant amount of energy: in city driving, a gas car loses approximately 30% of the engine output during braking. With this hybrid, the small battery pack is constantly recharged during driving, either through regen braking or by the engine. This means the car doesn't have to be plugged in. In essence, this hybrid is designed to provide the performance of a gas car with lower emissions and higher fuel economy. However, this car never achieves zero emission operation. The Honda Insight is an example of this type of hybrid (see description below under *Availability*.)

Another type of hybrid uses both the electric motor and the engine to drive the wheels. This arrangement allows greater flexibility in responding to driving conditions. At a stop, the engine may shut off, eliminating idling emissions. The electric motor may work alone at low speeds, allowing the vehicle to be zero emission in neighborhoods or urban areas, for example. The engine will take over at higher speeds, when more power is needed. Typically, these cars use a relatively small battery pack and are not plugged in; the engine recharges the batteries while the car is in operation. The Toyota Prius is an example of this type of hybrid (see description below under *Availability*).

Hybrids that use only the electric motor to drive the wheels (often called a series hybrid) are not being developed by the major automakers for commercial introduction at this time. This type of hybrid only uses the gas engine to supply energy to the battery or to the electric motor. This means the gas engine can operate steadily at an optimal speed, making it more fuel-efficient. Also, the gas engine can be shut off for zero emission operation. This type of hybrid can be plugged in, which translates into greater reductions in pollutants and CO2 emissions reductions, especially if the electricity is being generated by non-fossil fuel sources. However, the major automakers are focusing their efforts on hybrids that do not need outside recharging in order to make the users' experience of the hybrid "transparent".

Performance, Infrastructure and Emissions

Performance

As noted above, hybrid vehicle performance is quite comparable to that of a regular gas car. The Toyota Prius, for example, accelerates from 0 – 60 in 12 seconds (by comparison, the MY 2000 Camry gets from 0 – 60 in 11.1 seconds) and has a maximum speed of 100 mph. Honda says the Insight's acceleration is comparable to that of an ordinary gas car with a 1.5 liter, 4-cylinder engine.

Test Driving the *Prius* and *Insight*

Both Honda and Toyota have provided journalists the opportunity to test drive their respective hybrids. Articles reporting on these journalists' impressions are attached to this study. The following are a few sample quotes from these articles:

"After several days' driving in "real" traffic conditions, including motorways … the car patently makes its own case."
Financial Times, 10/9/99

"The Insight makes a convincing demonstration. The car moved easily in the flow of high-speed commuter lane traffic on Interstate 93 just outside Boston on a recent week-long test drive. When the digital speedometer read 75 miles per hour, a moving bar graph just below the speedometer indicated the car was getting 42 miles per gallon of gasoline."
Boston Globe, 12/6/99

Since hybrids such as the Prius and the Insight do not rely primarily on battery power, they would seem to offer no special concerns for cold weather driving.

Infrastructure

Neither the Prius nor the Insight needs to be plugged in. Drivers simply fill up the gas tank as usual. All of the major automakers have indicated their intent to develop hybrids that do not use off-board charging.

Emissions and Fuel Economy

The Honda Insight meets California's Ultra Low Emission Vehicle standard. Toyota is developing an U.S. version of the Prius that will meet the Super Low Emission Vehicle standard.

Both the Honda Insight and the Prius have mileage ratings about twice that of comparable cars. However, depending on how the hybrid is designed, the fuel economy savings may differ

Availability and Cost

As has already been discussed, Toyota and Honda are the first auto manufacturers to offer hybrids in the U.S. The Honda *Insight* went on sale last December, and the *Prius* will be available sometime around mid-2000. Toyota plans to sell about 1,000 units per month at a base sticker price of $18,800. Honda has said they only plan to make 4,000 to 5,000 *Insights* available.

Toyota Prius The Toyota Prius is the first mass-produced hybrid-electric vehicle. The 4-door, 5-passenger sedan is equipped with a 1.5 liter, 4-cylinder engine, an electric motor, and a nickel-metal hydride battery pack. A complex onboard computer system determines whether the car is being propelled by the gas engine, the electric motor or the two in combination. When starting out, at low speeds and while idling, the electric motor alone drives the car. At higher speeds, the gas engine kicks in, with the electric motor providing an assist during acceleration; the electric motor shuts off entirely during highway driving. The batteries are recharged by the gas engine and by regenerative braking, so the Prius does not require plug-in charging.

According to Toyota, the Prius achieves 55 mpg in the U.S. combined driving cycle. Toyota also reports that the Prius reduces emissions of nitrous oxides and carbon monoxide by 90%, and cuts hydrocarbon emissions by 75-90%, qualifying the car as a SULEV.

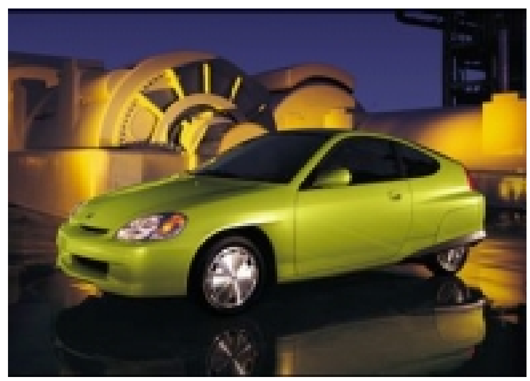
Toyota plans to price the Prius at under $20,000 when it brings the car to the U.S. market in mid-2000.

More information on the Toyota Prius can be found at http://www.toyota.com/afv/prius/intro_prius.html

Honda Insight *Honda* launched its hybrid-electric Insight in the U.S. last December – the first Insights were delivered in California; Northeast dealerships received delivery in January. The compact two-seater topped the EPA's fuel economy list for model year 2000 cars with a mileage rating of 61 mpg in city driving and 70 mpg on the highway. With its 10.6 liter gas tank, this mileage means the Insight can travel from 600-700 miles on a single fill-up. The comparably sized Civic gets about half that – 28 mpg in the city, 35 mpg on the highway. As for other emissions, the car meets California's ultra-low-emission vehicle (ULEV) standards.

The Insight's high fuel economy is as result of both the hybrid-electric powertrain and an extremely lightweight aluminum body. The car runs primarily on gasoline, with an electric motor that assists during acceleration and recharges the batteries during braking and deceleration – energy lost as heat and friction in regular gas cars. The electric motor means the gas engine is significantly scaled down –a 1.0 liter, 3-cylinder engine, as opposed to the similarly sized Civic's 1.6 liter engine. The vehicle's nickel-metal hydride battery pack is continuously recharged during driving, so, like the Prius, the Insight does not require off-board charging.

The Insight's MSRP is $18,880 or $20,080, depending on whether the car is fully loaded. Honda only plans to sell between 4,000 and 5,000 units of this car. Thus far, demand has outstripped production of the Insight. Honda dealers have taken advance orders for over 200 Insights. Honda plans to ramp up production to 300 units per month soon.



Information on the Honda Insight can be found at http://www.honda2000.com/models/insight/index.html

DaimlerChrysler Durango Late last year, DaimlerChrysler unveiled a hybrid version of its Dodge Durango. In yet another variation on the hybrid drivetrain, the hybrid Durango is equipped with an electric motor that powers the front wheels, while 3.9-liter V6 the engine drives the rear. The addition of the electric motor means hybrid Durango will have the same power, acceleration and performance provided by a conventional V8 engine Durango. The hybrid SUV gets 18.6 mpg, compared to 15.5 mpg of the regular Durango -- a 20% improvement. DaimlerChrysler announced that this version of the Durango would cost $3,000 more the conventional Durango; however, the company used the Durango unveiling to urge Congress to pass a $3,000 tax credit for hybrids and said they would not introduce the Durango without such a purchase incentive.

General Motors Hybrid-Electric Pickup In 1999, GM announced that it would be deploying a small fleet of hybrid-electric pickup trucks in New York and California in 2000. Although the company provided few details, a GM spokesman said GM planned to test 10 Chevrolet Silverado and GMC Sierra pickups equipped with both a gas engine and an electric motor with a lead acid battery. These vehicles will be placed into GM's own fleets as a test ground for hybrid technology in larger vehicles, where they think hybrid technology may provide the most benefits. GM said it views hybrids as a near-term solution for improving fuel efficiency and emissions, until fuel cells become commercially viable**.**

Future Outlook There seems to be a consensus in the automotive industry today that hybrids will be the primary electric alternative to gasoline vehicles in the immediate future. Ford Chairman William Clay Ford Jr. recently said that he thinks hybrids will comprise 20% of vehicle sales by 2010. Robert Bienenfeld, Manager of the Alternative Fuel Task Force at American Honda Motor Company was recently quoted on CNN.com saying that, in the next 5 – 10 years, virtually every automaker will probably come to market with a hybrid.

Under a federal initiative called the Partnership for a New Generation Vehicle (PNGV), the U.S. Big Three have all committed to introducing 80 mpg cars by 2003; hybrids are the designated technology for reaching this mileage goal in the near term. The autos are required to present demonstration cars this year, and, at the January Detroit Auto Show, both GM and Ford showed their PNGV prototypes. The five-passenger Precept uses a diesel engine and electric motor to achieve approximately 80 miles per gallon. The car body is made with lightweight aluminum and plastics, as is the Ford Prodigy. The five-passenger Precept gets 70 mpg with gasoline, and 80 mpg with diesel. Both automakers have said these cars will not advance to production models. Rather, they are working prototypes to test and demonstrate hybrid technology.

In February, DaimlerChrysler just unveiled its PNGV prototype, a hybrid version of the Dodge ESX3 sedan. The ESX3 uses a 1.5 liter direct injection diesel engine and electric motor that powers the front wheels. It is equipped with a small lithium-ion battery. DaimlerChrysler says the car gets 72 mpg and has a range of 400 miles. Although the hybrid ESX3 will likely never be mass-produced, DaimlerChrysler did note that this car would only carry a price premium of $7500 over the cost of a comparable sedan. The vehicle's lower pricetag results in part from the use of a plastic body frame that's cheaper and easier to make than a steel or aluminum car.

Finally, GM has also shown a concept hybrid SUV. The Chevrolet Triax, unveiled at the 1999 Tokyo Auto Show, has an electric motor in the front of the vehicle; the rear third of the vehicle holds the internal combustion engine; and the middle third houses the vehicle's batteries.

Gasoline SULEVs

Definition

The California Air Resources Board defines a SULEV as a vehicle that achieves a 96% reduction in hydrocarbons, a 95% reduction in nitrogen oxides, and a 70% reduction in carbon monoxide, as compared against vehicles meeting the current basic standard. In addition, vehicles that meet the SULEV standard, have no evaporative emissions and meet the requirements for On Board Diagnostics, qualify for zero emission vehicle credits under the ZEV mandate.

Availability

CARB has designated two internal combustion engine cars for model year 2000 as SULEVs meeting the ZEV mandate: the Honda S2000 Accord and the Nissan Sentra CA. The S2000 Accord has a 2.3 liter, 4-cylinder engine. It achieves SULEV emissions reductions with advanced Ultra-Low Emission Vehicle technology and new catalytic converter technology. The car, which was due to become available in February, is priced at $23,200, only $100 more than the model it is replacing.

The smaller Nissan Sentra CA has a 1.8 liter engine and is also equipped with advanced environmental technologies that, in addition to reducing tailpipe emissions, allow the car to emit no gasoline vapors. According to Nissan, a Sentra CA that was driven for a 20-mile round trip commute would emit fewer harmful vapors than a car sitting in the driveway all day long. The Sentra CA does require low-sulfur fuel, available only in California, to achieve its emissions reductions. The Sentra CA is scheduled to go on sale in California in February.

Fuel Cell Vehicles

Fuel cell vehicles are still in the prototype stage; however, most of the major automakers are investing heavily in development of this new technology, and are predicting that fuel cell cars will be ready for commercial introduction within this decade. Fuel cell vehicles offer the possibility of zero emission operation with no recharging and with high performance.

Definition

A fuel cell produces electricity from the reaction of hydrogen and oxygen. Hydrogen is passed through the fuel cell, where it is separated into an electron and a hydrogen ion. There are different types of fuel cells under development, but essentially, what happens is that the ions combine with oxygen, creating water, while the electrons are directed to the electric motor. The only by-product of this process is water - there are no pollutants and no carbon dioxide emissions. This process is much more efficient than the internal combustion process - as much as 2 or 3 times more efficient.

A significant issue with fuel cell vehicles is how to supply the hydrogen. There are different methods of providing the hydrogen "fuel" to the fuel cell, and some of these have emissions associated with them. If the hydrogen is stored on board, the vehicle is truly zero emission. However, most automakers are considering a different method: deriving the hydrogen from another fuel, such as methanol or gasoline, that is stored on the vehicle. "Reformation" of methanol and gasoline would produce some air pollution, although significantly less than an internal combustion vehicle. Reformation also results in CO_2 emissions. Because the fuel cell is more efficient, CO_2 emissions are reduced by about half.

Availability

All of the major automakers are working on fuel cell vehicles, with target commercialization dates in the 2003 – 2005 timeframe.

DaimlerChrysler has made the most progress towards developing a commercially viable fuel cell vehicle. Earlier this year, the automaker unveiled the fourth generation of its fuel cell-powered Mercedes A-Class hatchback and has made a commitment to introduce the fuel cell A-Class by 2004. The A-Class is a subcompact that fits five people. The fuel cell, manufactured by Ballard Power Systems, is fed by an on-board methanol reformer, giving the car a 50% reduction in CO_2 emissions.

In 1997, Ford entered into a highly publicized alliance with what was then Daimler-Benz to develop fuel cell cars for commercialization by 2004. This year, Ford reiterated its goal of commercialization by 2004 when it unveiled a fuel cell concept car, the FC5, at the Frankfurt Auto Show. Ford says the 5-passenger FC5 “offers a realistic look” at what kind of fuel cell car will be ready for low-volume production by 2004. The FC5 also features a Ballard fuel cell stack and on-board methanol reformer.

GM and Toyota have also teamed up to develop a fuel cell car or truck for commercial introduction by 2003 or 2004. Honda has announced that it intends to make a fuel cell vehicle available by 2003.